
A lake in the moraine wall of Jichu Drake glacial lake.

How Yak Farmers Can Hold Back a Glacial Tsunami

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As Himalayan glaciers melt, the natural dams formed beneath them become a dangerous threat to villages below. However, local yak farmers could soon have a simple solution.

It was September 2013, just after the monsoon season. As we climbed up a long, windy and muddy track towards the "Roof of the World" my heart raced and chest heaved from the effort required to extract oxygen from the rarefied air.

I asked myself: "Why am I doing this?" The answer was that I was there to help the people of Bhutan find a cheap and sustainable way to drain water from glacial lakes to reduce the risk of glacial lake outburst floods (GLOFs).

The Himalayan kingdom of Bhutan is a small country of 700,000 inhabitants, and covers an area about as large as Tasmania or Switzerland. Bhutan is one of the most environmentally proactive countries in the world. Seventy per cent of Bhutan is covered in forest, and by law this figure is not allowed to fall below 60%.

As well as having an exemplary environmental record, Bhutan is also famous for its policy of "Gross National Happiness". Its parliament makes decisions not on what is going to generate the greatest material wealth for the country, but what is going to contribute to the overall happiness and well-being of the nation.

However, like many developing countries, Bhutan is suffering from the side-effects of the developed world's rapid economic development since the Industrial Revolution.

The problem is that the dramatic increase in the average temperature of the Himalayas since the 1950s has resulting in the melting of its glaciers, and the naturally formed lakes at the head of the glaciers have increased in area and depth. Glacial lakes are held in place by a natural dam wall formed by loose rock and stones carved out of the mountains by the glacial ice.

As the water in the lakes gets deeper, the pressure at the base of the dam wall increases and the risk of it breaching increases. Furthermore, when the water is near the top there is a danger it will start to flow over the top, resulting in runaway erosion of the dam wall. In the summer, avalanches can occur when snow and ice falls into the lake, creating a tidal wave that could easily breach the dam wall if the water level is close to the top.


Ponies loaded with equipment. Each coil of tubing on the backs of the ponies a contained 100-metre length of polypipe.

On 7 October 1994, the moraine wall of Luggye glacier in the Thorthormi region of Bhutan burst open, sending a wall of 18 million cubic metres of water crashing down the Pho river valley, killing 21 people and devastating homes and farmland.

With such a reputation for destruction, GLOFs are often called inland tsunamis. A basic calculation reveals that the total amount of energy released in the 1994 GLOF was equivalent to at least 16 of the atomic bombs dropped on the Japanese city of Hiroshima at the end of World War II. There is no doubt that GLOFs are increasingly likely in a warming world.

Nepal is an earthquake-prone region, and earthquakes are another way GLOFs can be triggered. It stands to reason that full lakes are more prone to earthquake damage.

Between 1963 and 1993, a total of 103 glaciers were monitored in Bhutan. Over this 20-year period, 87 shrunk by an average of 6 metres (range 1–26 metres) while the others stayed the same size. The situation certainly hasn't improved in the intervening 22 years since the end of that study. Recent statistics show that some glaciers in the world are now receding by more than 100 metres each year!

In the 2012 documentary *Chasing Ice*, photographer James Balog travelled to glaciers in Alaska, Greenland and Iceland, and chronicled their decline over a 3-year period. At one point the team arrived to take a follow-up photo of a glacier and couldn't see it anywhere. They assumed they were in the wrong place but then, to their dismay, they discovered they had come back to the right spot – the glacier had shrink so much it had disappeared over the horizon! Although no Bhutanese glaciers were featured in *Chasing Ice*, no doubt the story there is much the same.

Mountains of evidence exist that glaciers are in rapid retreat – in fact there are hardly any mountains that do not contain evidence of glacial decline. However, there are a few minor exceptions to the global trend. For example, the Fox and Franz Josef glaciers in New Zealand sometimes advance – but then they retreat. We might think of these glaciers as "yo-yo" glaciers that go up and down and up again. It's important to note that on balance, these Antipodean glaciers have shrunk by more than 2.5 km in the past century. Hence it's unwise to point to these rare examples of momentary advance and ignore the thunderous roar of glacial retreat elsewhere in the world.

In some ways, glaciers are like a seesaw – on one side is snowfall while on the other is melting water. Melting *per se* is not bad: glaciers are meant to melt, and this is the source of water for many of the world's mightiest rivers. For example, the Jichu Drake glacier, just above where we were performing our experiments, feeds the Brahmaputra River.

When a glacier is in balance, the amount of ice melting at the bottom is equalled by the amount of new ice formed from compacted snow at the top. But in Bhutan, the glaciers are shrinking and the snowfall is declining. The frightening implication is that the glaciers in Bhutan, and many other places in the world, are fast becoming extinct.


Som Gurung of the Royal University of Bhutan measuring the temperature of the water flowing from the glacial lake.

Our expedition to Bhutan in September 2013 was not so much to demonstrate that siphons can operate at high altitude, and hence prevent a glacial lake from overflowing, but rather to explore the logistics of transporting the tubing and ancillary equipment required for a glacial lake siphon.

A siphon is an n-shaped tube with its outlet lower than its inlet. The middle of the siphon is higher than the upper reservoir of water. Because the pressure inside the siphon is lowest at the siphon's apex, water can be drawn up from the glacial lake and passed over the dam wall without any need for digging.


Prof Les Dawes of QUT directing water from the siphon into a bucket to measure the flow rate.

The maximum height of a siphon – the difference between the water level in the lake and the highest point of the siphon tube – depends on the ambient atmospheric pressure. Atmospheric pressure at 4400 metres – the height of many glacial lakes – is only 60% of sea level pressure, and therefore the maximum siphon height is 6 metres. Above this height, the pressure at the apex is less than the vapour pressure of water, so the water will boil and the column of water will break.

At the Jomolhari base camp I grabbed a temperature probe and stuck it in some boiling water – it was only 86.7°C due to the reduced atmospheric pressure. Our siphon was 3 metres high, so we were OK. If it was 6 metres high, the water would have boiled even though the air temperature was only 8°C.

The challenge of our expedition was to get all the required equipment to 4 km above sea level on the backs of ponies as there are no roads above about 3 km. We made it, but we had to lug the equipment ourselves onto the moraine wall as even the ponies could not get there.

We stayed on the moraine wall for several hours and tried to get our 70-metre-long siphon going. The intermittent rain made it difficult to clamber over the boulders. Eventually, we managed to get the siphon going but it stopped after about 10 seconds as the inlet jumped out of the water. We persevered and managed to get the siphon flowing continuously and make some flow measurements just before we had to leave. We dismantled the siphon after the test.

We learnt many valuable lessons. For example, next time we need to take two-way radios as it is impossible to communicate between the two ends of the siphon due to the roar of the water from the nearby streams.

We now need a bit more money for the next stage of the project. We plan to perform some experiments at Lake Manchester, about 27 km west of the Brisbane CBD. Lake Manchester, built in 1912–16, was the main water supply for Brisbane, a role now taken over by Wivenhoe Dam – a much bigger dam for a much bigger city.

Some of the dam walls in Bhutan are several hundred metres wide, so a siphon would have to travel this distance before descending over the dam wall. Over the next few months we plan to do some experiments with a siphon that is 500 metres in length using one-inch and two-inch bore tubes – since this is the largest diameter that can be transported on the backs of ponies. These experiments will give us vital information for another experiment in Bhutan, and pave the way for the widespread deployment of siphons at glacial lakes throughout Bhutan.

Ultimately, our plan is to train the local yak farmers in Bhutan to deploy siphons in the spring, and run them through the summer and autumn to prevent the lakes from overflowing. (A yak farmer helped us set up the siphon on our expedition – his house was just below the dam wall.) The yak farmers will be able to monitor the water level in the dams and add more siphons as necessary.

We are hoping that this will be a cost-effective way of controlling the water level in glacial lakes in Bhutan and the rest of the world. The cost of our expedition over a 6-day period was AUD$1600 – this included food for six people, tents, ten ponies, 500 metres of one-inch diameter polypipe tubing, connectors, valves and taps. It is difficult to envisage any other method as cost-effective and sustainable as this.

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